The Sub-Plate Method and Wide-Field Astrograph Plates

With the invention of the sub-plate technique (Taff 1989), the problem of reducing Schmidt plates in an astrometric fashion has been successfully solved. As one result of this success, NASA has provided funds to us to make the sub-plate code portable and therefore available to all. Given this enlarged future usage of the strategy, we have looked for additional problems for it. An obvious likely application is to *wide-field* plates taken with an astrograph. We have analyzed a set of 64 wide-field astrograph plates, each covering $11^\circ \times 11^\circ$, both by the sub-plate algorithm and the traditional approach. These 64 plates comprise the 'South Polar Cap' region of the Yale catalogs (Hoffleit 1971). The plate material is described in Lü (1971). Herein we merely note that the original reduction was with a ten constant plate model in each coordinate. The tenth term is a color index/coordinate term. Finally, these plates were measured by hand and have rather large measurement errors. The estimated standard deviation about the mean of the x and y values is $0''.4$ after conversion from microns via the plate scale.

Both the original reduction of this material (Lü 1971) and our own preliminary analysis — using spectral type as a substitute for color index (Lang 1992) — led us to believe that the presence of the color index term was superfluous. Thus, the global plate model we used between x, y and ξ, η was:

$$\begin{aligned} x &= a + b\xi + c\eta + d\xi^2 + e\xi\eta + f\eta^2 + g(m - m_0) + h\xi(m - m_0) + i\eta(m - m_0) \\ y &= A + B\xi + C\eta + D\xi^2 + E\xi\eta + F\eta^2 + G(m - m_0) + H\xi(m - m_0) + I\eta(m - m_0) \end{aligned} \quad (1)$$

where m is the apparent magnitude of a star and m_0 is the average apparent magnitude of all the stars on this plate.

Using the Astrographic Catalogue Reference Stars (ACRS) work of Corbin & Urban (1988) as a reference catalog (all our work was repeated using the Positions and Proper Motions catalog of Roeser & Bastian [1989] as a substitute), we re-reduced an entire plate. No use was made of the 50% geometrical overlapping of the plates.

One difficulty not encountered in our earlier Schmidt plate work was the off-centering and rotation of some of these plates. Without investing the time and effort to first solve for the necessary translation and rotation parameters, some plates could not always be fully covered with our basic sub-plate pattern of 8×8 (or 15 stars per sub-plate). Hence, they suffer from either a lack of full areal coverage or of larger than desired sub-plates owing to this artificial difficulty. When this is the case and the results from the sub-plate technique are locally poor, we attribute the inferior results to this geometry problem and have deleted the plate from further consideration in the error statistics below. This occurred, repeatedly, for the same three plates. There were also a few, 3, bad stars in the files for they were rejected by both techniques (and both the PPM and ACRS models). The five plates they were on were also eliminated from further consideration.

As has been shown to be beneficial in our sub-plate work, we always use an external, objective standard of comparison to evaluate our results. Internal, mathematically generated measures of goodness-of-fit are all too often worthless or worse, misleading. Given the far southerly declination of this plate material and our desire to have a dense coverage of the field-of-view, we have chosen the International Reference Star catalog (Corbin 1991) as the comparison catalog. Just to be clear, since we used the International Reference Star catalog as our test criteria, those IRS stars in either the ACRS and PPM were deleted from our versions of the latter star catalogs before any plate solutions — whether traditional or sub-plate — were performed. On the average, there were 846 ± 123 ACRS stars per plate after 72 ± 10 IRS stars have been deleted (the corresponding PPM numbers were

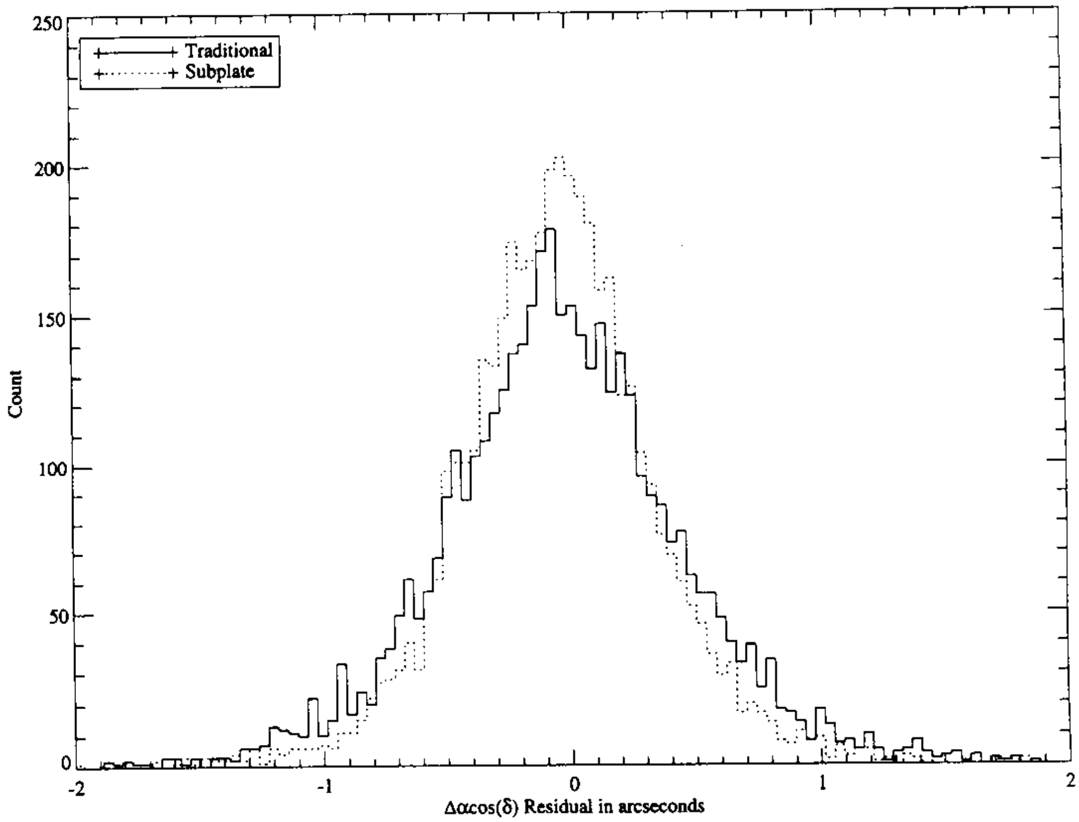

Figure 1a. Distribution of the residuals in right ascension on a great circle for the sub-plate and traditional solutions (based on the ACRS catalog) and the IRS values. The dashed curve is for the sub-plate algorithm and is noticeably more centrally peaked and narrower than for the customary method.

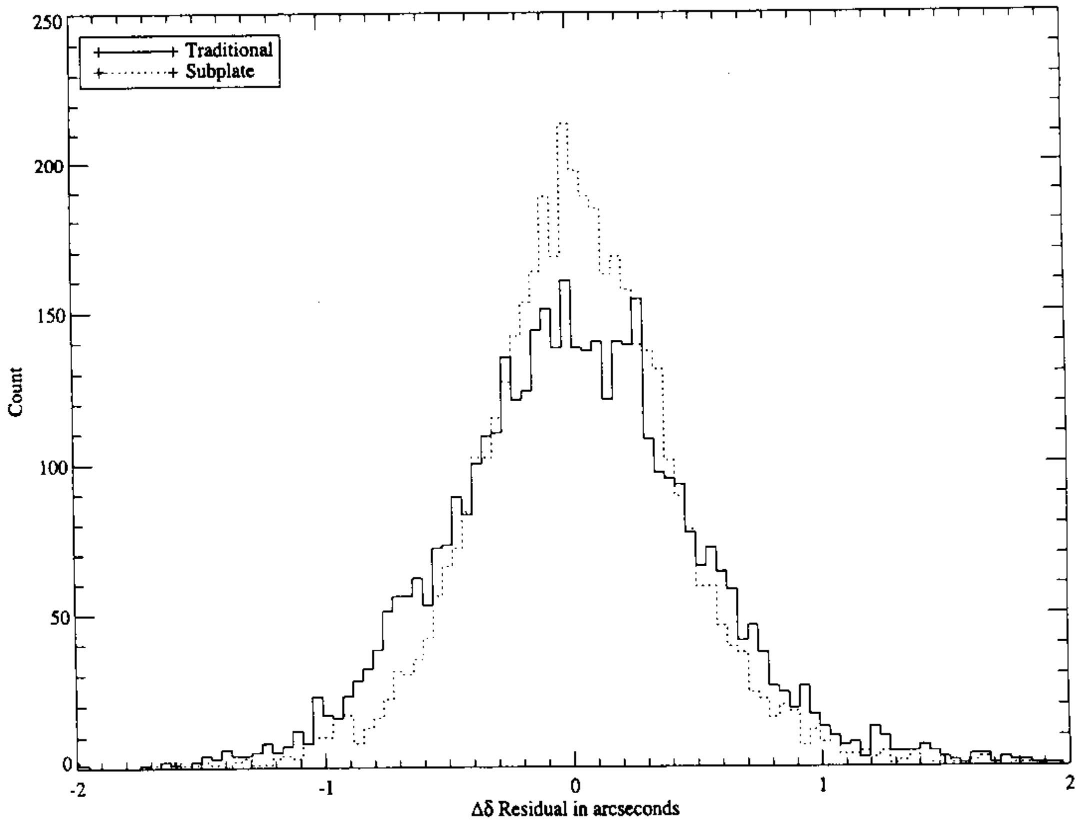

Figure 1b. Same as Fig. 1a but for the declination residuals. The reduction in width is 22% in both cases.

1011 ± 129). This translates into 13.2 (15.8) reference stars per sub-plate in our nominal 8 × 8 basic pattern.

The standard deviation in the equatorial coordinate differences between the sub-plate position for an IRS star and the catalog value was 0''.403 and 0''.419. These values compare favorably to the estimated measuring standard deviation of 0''.4. Thus, the primary contribution to the final positional errors is measurement error. For the traditional method the corresponding values were 0''.490 and 0''.510, 22% higher than for the sub-plate results. (The comparable values for the PPM re-reduction were 0''.495 and 0''.510). The distributions of the equatorial coordinate residuals are shown in Figs. 1a and 1b. Clearly the sub-plate approach is superior, on these *wide-field* astrograph plates, to the traditional, global plate model algorithm employed herein. More of the plates reduced the sub-plate technique have mean errors closer to zero than not and the wings of the sub-plate distribution in Figs. 1a and 1b are narrower than the wings of the traditional method's distribution. The effect is a consistent 22%, in both equatorial coordinates, as measured by the standard deviations about the mean of their distributions.

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References

Corbin, T.E., 1991. International Reference Stars Catalog (U.S. Naval Observatory, Washington, DC).

Corbin, T.E. and Urban, S., 1988. In 'Mapping the Sky', IAU Symposium No. 133, ed. H. Eichhorn, Reidel, Dordrecht, p. 287.

Eichhorn, H., 1960. *Astron. Nachr.*, **285**, 16.

Hoffleit, D., 1971. Trans. Yale Univ. Obs., **31**.

Lang, K.R., 1992. Astrophysical Data: Planets and Stars, Springer-Verlag, Berlin, p. 137.

Lü, P.K., 1971. Trans. Yale Univ. Obs., **31**.

Roeser, S. and Bastian, U., 1989. Positions and Proper Motions for 181731 Stars North of Declination -2°.5 for Equator and Equinox J2000.0, Astronomischen Rechen-Institut, Heidelberg.

Taff, L.G., 1989. *Astron. J.*, **98**, 1912.

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